FOREST RESEARCH NOTE

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Reliability of Balsam Fir Growth and Yield Estimates Based on Black Spruce Normal Yield Tables

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Introduction

Ontario's pulp and paper industry relies primarily on black spruce (*Picea mariana* (Mill.) B.S.P.). However, supply shortfalls are anticipated (Reed 1980) and balsam fir (*Abies balsamea* (L.) Mill.) is an important alternate source of high-quality conifer fibre.

The normal yield tables developed by Plonski (1956, 1974) are used routinely by forest managers in Ontario. Since balsam fir is not included in the yield tables, the values for black spruce are commonly substituted. This study examines the validity of applying Plonski's black spruce normal yield tables to obtain growth and yield estimates for balsam fir in northern Ontario.

Methods

Fifty 0.04 ha plots were established in upland balsam fir stands in northwestern Ontario between latitudes 48°20′ N and 50°20′ N, and between longitudes 86°50′ W and 90°20′ W. The plots were located in Site Regions 3W and 4W of Hills (1961). Each plot contained a minimum of 75% fir by basal area and was free of obvious recent disturbances. The stands ranged from 35 to 110 years of age and were located on basal till soils of sandy loam texture (Ontario Institute of Pedology 1985).

Field sampling was conducted during the summers of 1980, 1981, and 1982. The total height and diameter at breast height (1.3 m above ground) of all dominant, codominant and intermediate living trees were measured on each plot. An increment core was extracted at breast height from each tree, and the previous five radial increments were measured. Ten trees covering the diameter range on the plot were felled to obtain the average basal age and average height increment over the previous five years for each plot. The average height increment was assigned to each tree when calculating the total height at the beginning of the preceding five-year period. Dead overstory trees were examined to estimate the year of death. Measurements and increment cores were taken from trees which had died within the previous five years.

The gross total volume (GTV) of each sample tree was calculated using the volume formula for a true paracone (MacDonald and Forslund 1986). The present plot volume was based on breast-height diameters and total heights of living sample trees. The plot volume at the beginning of the preceding five-year period was based on diameters and heights reduced by five annual increments for living trees, and by (5−N) increments for dead sample trees, where N is the number of years since death. Per hectare values for both GTV and basal area were obtained by summing the individual tree values within each plot and multiplying by 25. The current annual increment (CAI) in volume was calculated by subtracting the total volume at the beginning of the period from the present volume and dividing by five. This method of CAI determination was also followed by Plonski (1956) in the construction of the black spruce yield tables.

The actual GTV and CAI for each plot were compared to the values predicted from the black spruce normal yield tables of Plonski (1974). The correct site class was selected using the average height and age of each sample plot. The stocking factor was calculated as the actual plot basal area per hectare divided by

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the tabular normal basal area for the same site class and age. This factor was multiplied by the normal GTV or CAI to obtain the estimated volume or increment for each plot. The above procedures for obtaining estimated growth and yield values are provided with the yield tables as standard instructions (Plonski 1974).

The applicability of Plonski's black spruce tables to northern Ontario fir was tested for the entire sample by regressing the estimated volumes and increments on the actual plot values. The chi-square test of Freese (1960) was used to determine the accuracy of individual plot estimates.

Results and Discussion

Ninety percent of the variation in estimated GTV was attributable to its linear regression on the actual volume (Table 1). The slope of the regression line for GTV was not significantly different from one, and the Y-intercept was not significantly different from zero, even at a probability level of 10%. The good relationship between estimated and actual GTV across the data range is illustrated in Figure 1. These results imply that the GTVs estimated from Plonski's black spruce yield tables could be used reliably in place of the actual fir GTVs throughout this data range.

In contrast, there was poor correlation between estimated and actual CAI (Table 1 and Figure 2). As the residuals from the CAI regression displayed a nearly constant variance about a mean of zero, weighting the variables would not improve the fit of the regression (Neter and Wasserman 1974). The slope and Y-intercept of the regression line were significantly different from one and zero, respectively, at the 1% probability level. The relatively large standard error of estimate implies significant random error, while the slope less than one and intercept greater than zero imply systematic biases. The latter produce overestimates near the origin and produce underestimates above approximately 2.5 m^3/ha/yr, the value where the estimated CAI equals the actual CAI (Figure 2). Thus, the use of estimated CAIs in place of actual CAIs would result in considerable inaccuracy across the data range.

Table 1 also indicates the much higher error associated with individual stand estimates for CAI (89.5%) than for GTV (24.5%). Thus a forester can have little confidence in the accuracy of CAI estimates when applying Plonski's black spruce tables to a fir stand in a local management unit.

The estimated GTV or CAI is obtained by multiplying Plonski's normal value at the correct age and site class by the stocking factor (ratio of actual to normal basal area):

$$[1] \quad Ve = (Vn) \bullet (Ga/Gn),$$

where Ve is the estimated GTV or CAI, Vn is Plonski's normal GTV or CAI, Ga is the actual stand basal area, and Gn is Plonski's normal basal area. Equation 1 may be rewritten as:

$$[2] \quad Ve/Ga = Vn/Gn = k,$$

where k is a constant for a given stand age and mean height. Therefore,

$$[3] \quad Ve = k \bullet Ga.$$

The simple linear relationship assumed in Equation 3 may be valid for GTV. According to Boudoux (1973),

$$[4] \quad GTV = f \bullet h \bullet Ga,$$

where f is the mean form factor and h is the mean stand height. Comparing Equations 3 and 4, the constant k in this case includes only the form factor and stand height. We know that height is a constant for a given stand age and site class. Form factor is not strictly a constant, as it varies between and within species according to stand and site attributes (Boudoux 1973, Husch *et al.* 1982). However, this study shows that the error attributable to form variation should not prevent the use of substitute tables for local stand volume estimation.

The validity of Equation 3 cannot be so readily confirmed when Ve represents CAI. One problem is that changes in stocking during the growth period are ignored in the application of normal yield tables. Furthermore, it is unlikely that stand volume increment is linearly related to total basal area because many factors besides stocking affect stand productivity. Attributes of stand structure such as the distribution of basal area by diameter class and the nature of crown interactions influence growth rates. Vigour status, extent of insect defoliation, pathological condition, and climatic pattern during the increment period are other important

TABLE 1. Comparison of balsam fir actual yield parameters to those estimated from Plonski's black spruce yield tables, using regression and chi-square analyses.

Parameter	r^2	SEE (%)[a]	Slope[b]	Intercept[c]	Error (±p%)[d]
Gross total volume	0.90	14.0	0.935	4.394	24.5
Current annual increment	0.21	34.3	0.248**	1.779**	89.5

[a]Standard error of estimate divided by mean of dependent variable, multiplied by 100.

[b]** indicates a significant difference from one, at the 1% probability level.

[c]** indicates a significant difference from zero, at the 1% probability level.

[d]Individual plot values can be estimated to within p% of the actual values at the 95% confidence level, as determined by Freese's chi-square test.

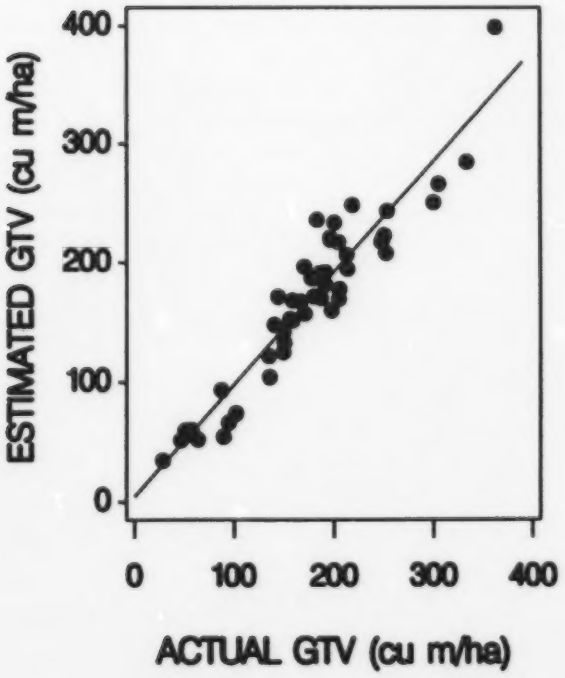

FIGURE 1. The relationship of estimated to actual gross total volume (GTV) of the sample balsam fir stands, based on Plonski's black spruce yield tables. The regression equation is: $Y = 4.394 + 0.935X$, $r^2 = 0.90$.

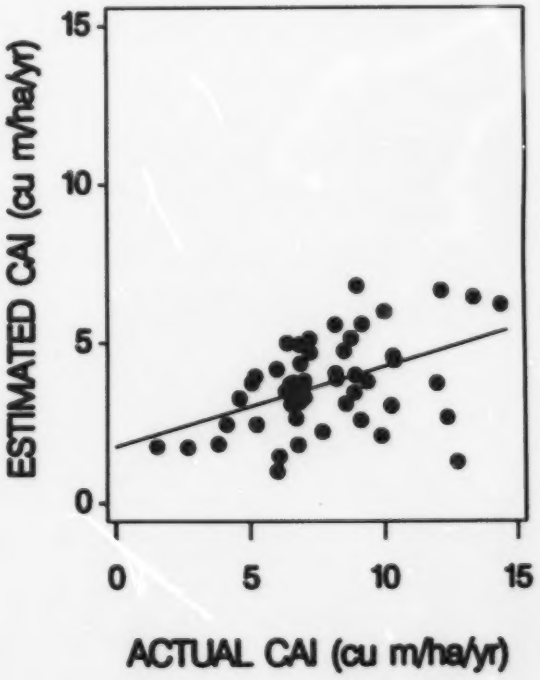

FIGURE 2. The relationship of estimated to actual current annual increment (CAI) of the sample balsam fir stands, based on Plonski's black spruce yield tables. The regression equation is: $Y = 1.779 + 0.248X$, $r^2 = 0.21$.

variables which influence the relationship between stand growth and stocking. Variations in these factors between the subject stands and the stands used to construct the yield tables cause inaccuracies in CAI estimates whenever normal yield tables are used. It is likely that such inaccuracies increase when tables for one species are used to estimate the increment of another species with an inherently different growth rate. The superior growth rate of fir compared to black spruce is implied by a slope which is considerably less than one in Figure 2.

Conclusions

As more of the under-utilized balsam fir stands in northern Ontario are brought into production, reliable growth and yield information will be required for the species. Accurate estimates of present yield can be obtained by conventional application of Plonski's black spruce yield tables to fir stands, avoiding the expense of developing local fir tables. However, substitute tables should not be used for balsam fir yield projection in crop plans because the factors controlling growth vary greatly between species and between regions. Fir growth models adaptable to local stand and site conditions should be developed as a more reliable basis for management planning.

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